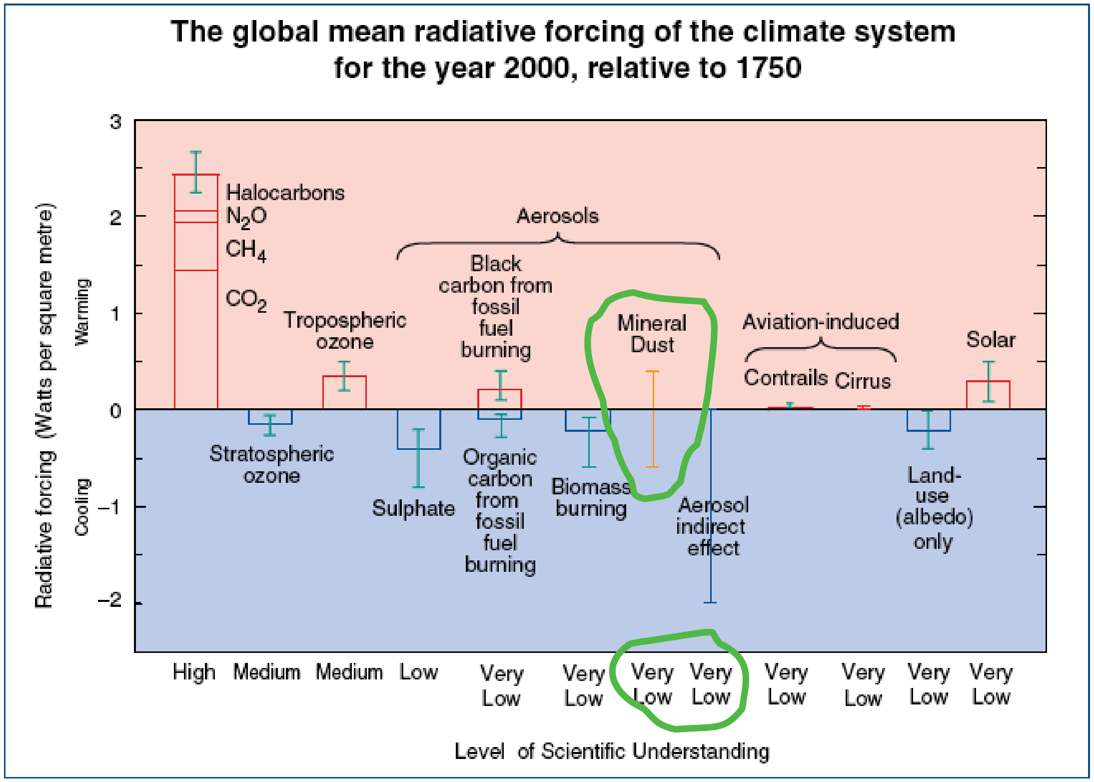
Global, Satellite-Remote-Sensing Aerosol Studies: What We Do, and Why It Matters

Ralph Kahn *NASA Goddard Space Flight Center*



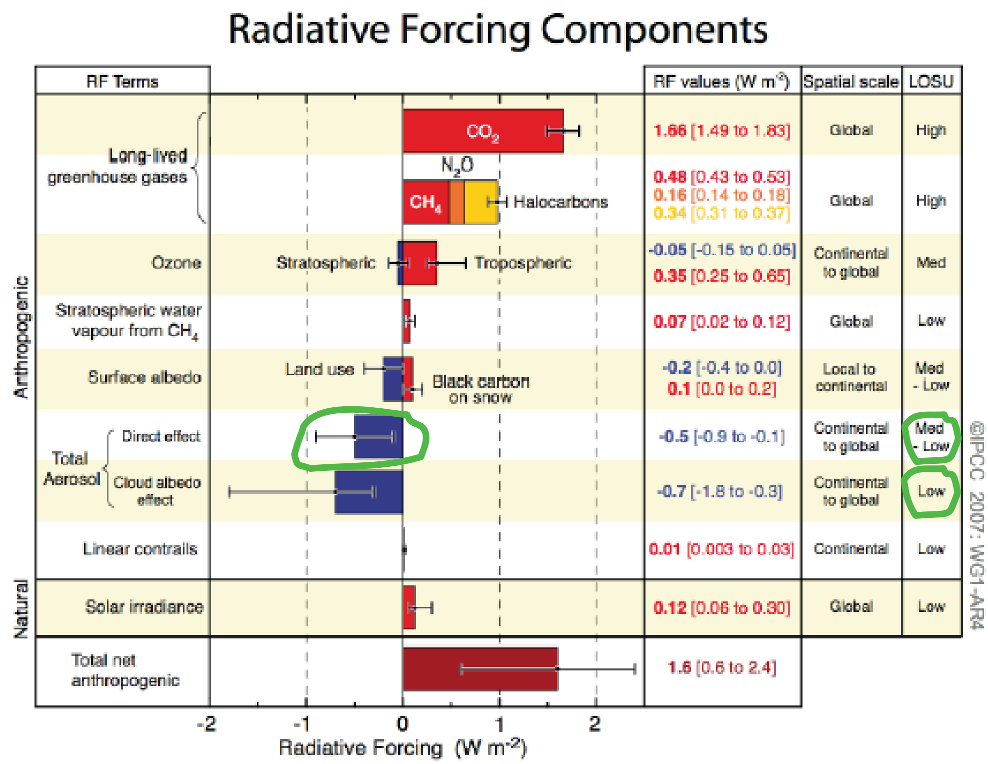
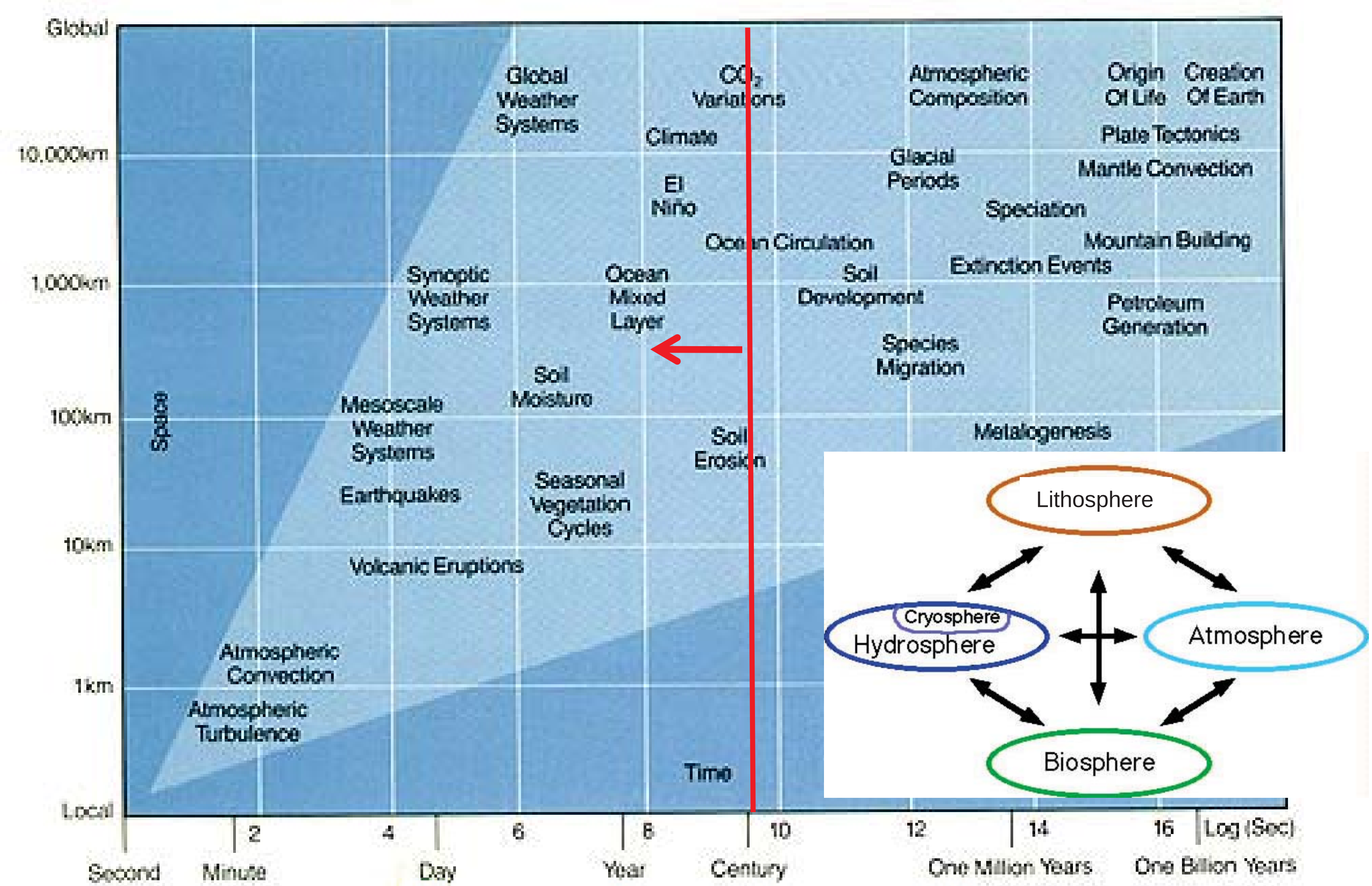


FIGURE SPM-2. Global-average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. Range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}

IPCC AR3, 2001
(Pre-EOS)

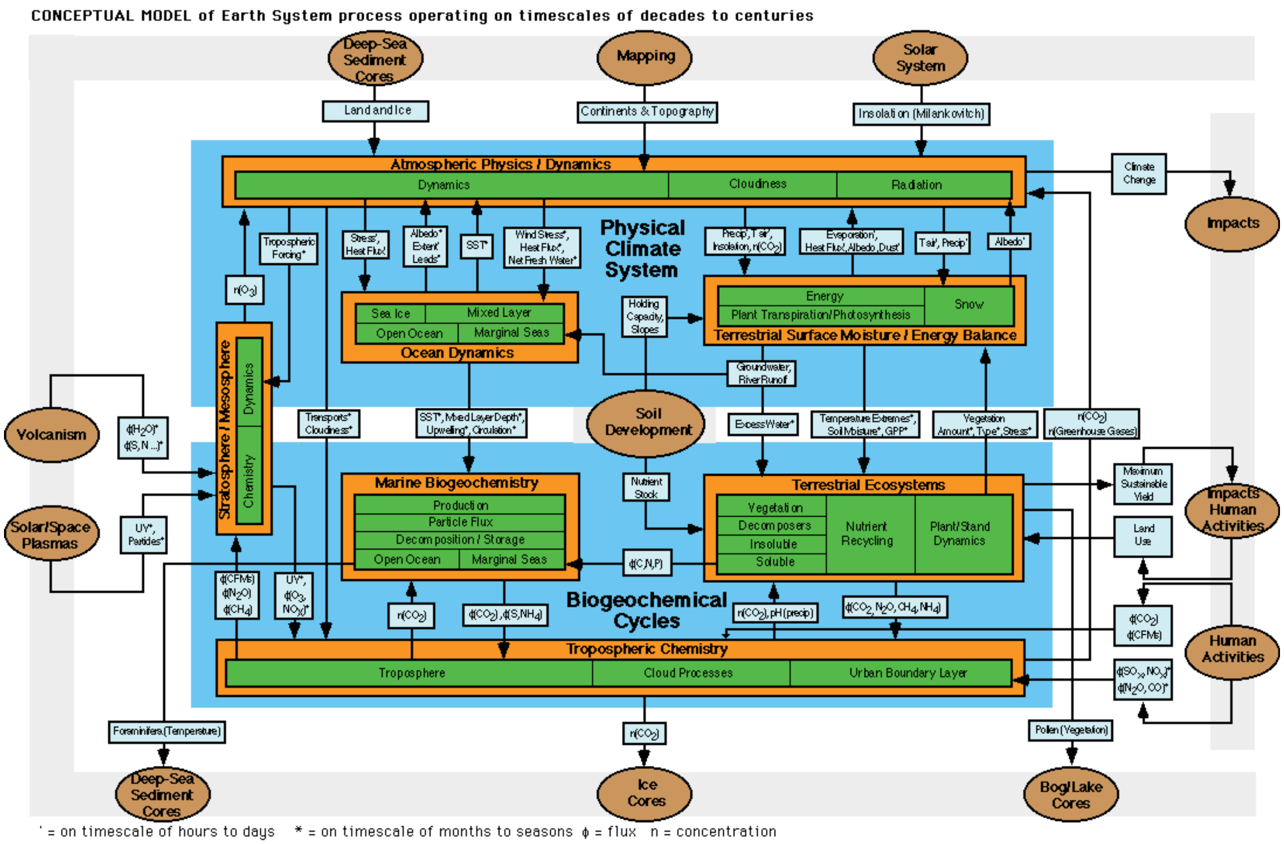
IPCC AR4, 2007
(EOS + ~ 6 years)

Earth Process Space & Time Scales



To account for the ***energy***, ***momentum***, and ***material*** budgets in the Earth System, exchanges among the ***atmosphere***, ***hydrosphere***, ***biosphere***, ***cryosphere***, & ***lithosphere*** must all be considered

What Drives Data Volume



"Betherton Diagram"

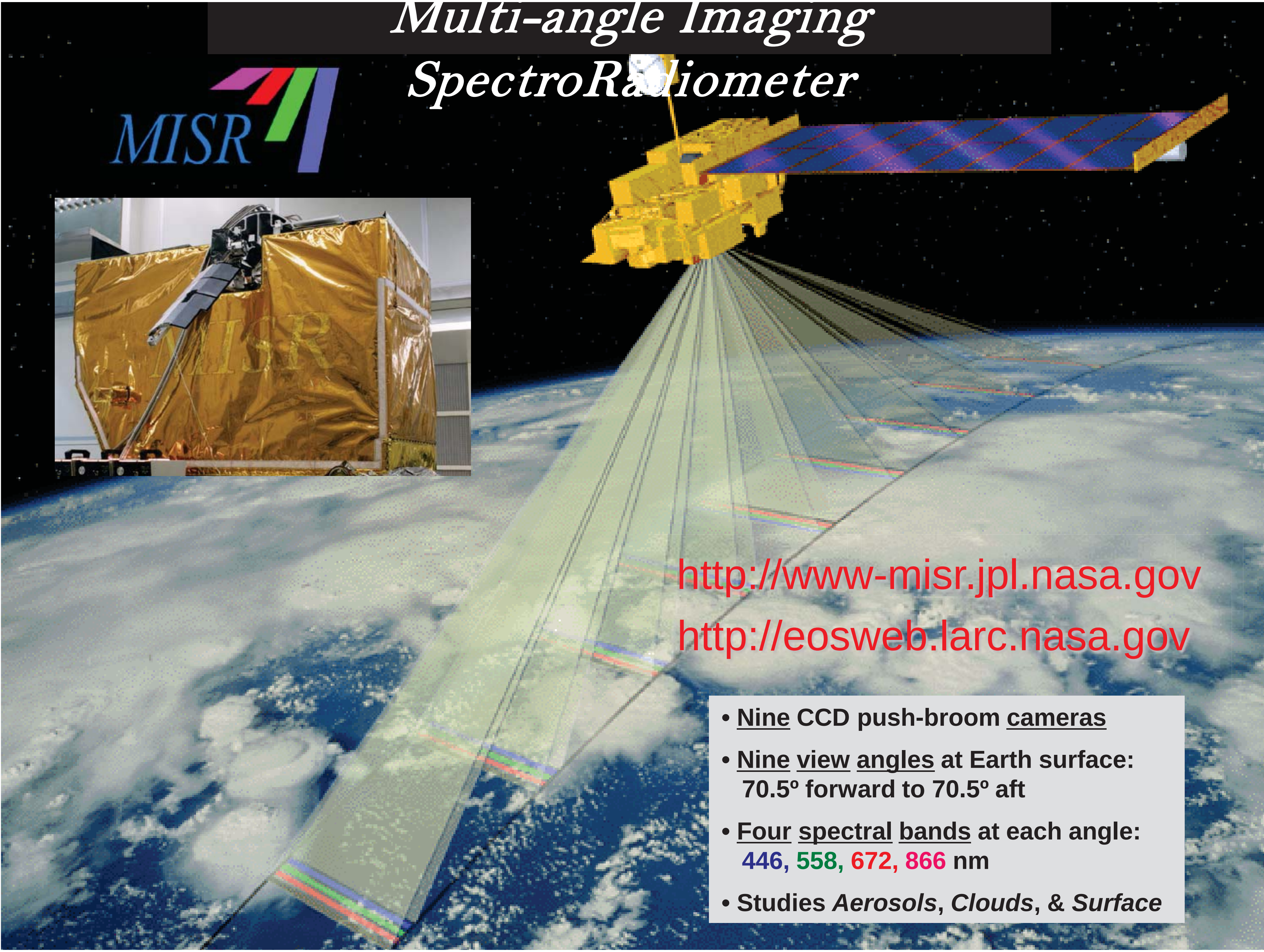
Average Radius of Earth = 6371 km

Area of Earth ~ **5×10^8 km^2**

~10 vertical elements, 100 horizontal elements/km, 100 parameters

Even with just 4 meas/day (to resolve diurnal cycle):

2×10^{14} meas/day [with 14-bit encoding] → **~ 3×10^3 Tbit/day!**


Multi-angle Imaging SpectroRadiometer
MISR
http://www-misr.jpl.nasa.gov
http://eosweb.larc.nasa.gov
• Nine CCD push-broom cameras
• Nine view angles at Earth surface: 70.5º forward to 70.5º aft
• Four spectral bands at each angle: 446, 558, 672, 866 nm
• Studies Aerosols, Clouds, & Surface

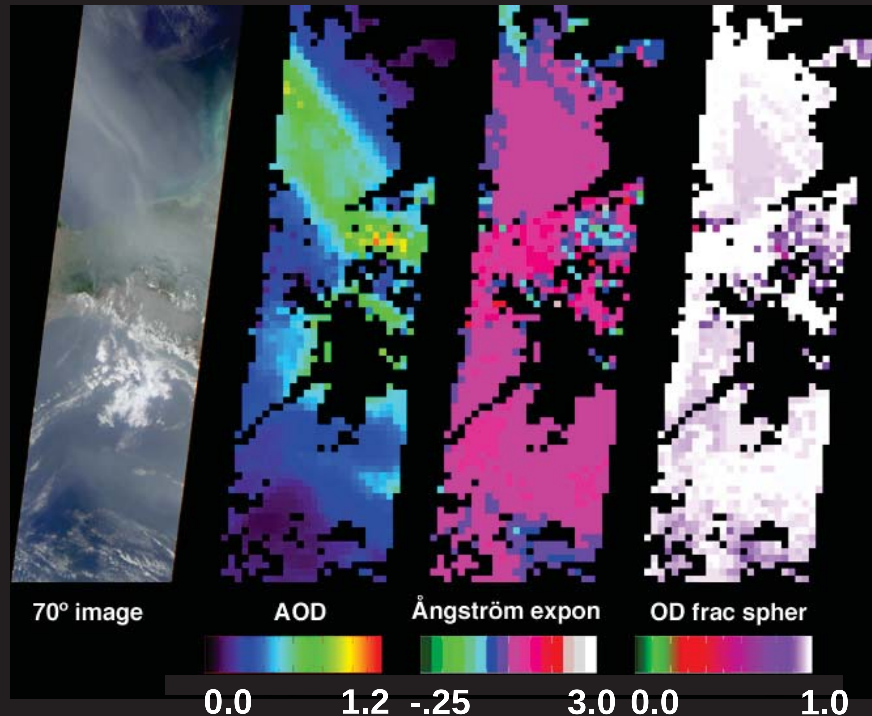
Smoke from Mexico -- 02 May 2002

Aerosol:

Amount

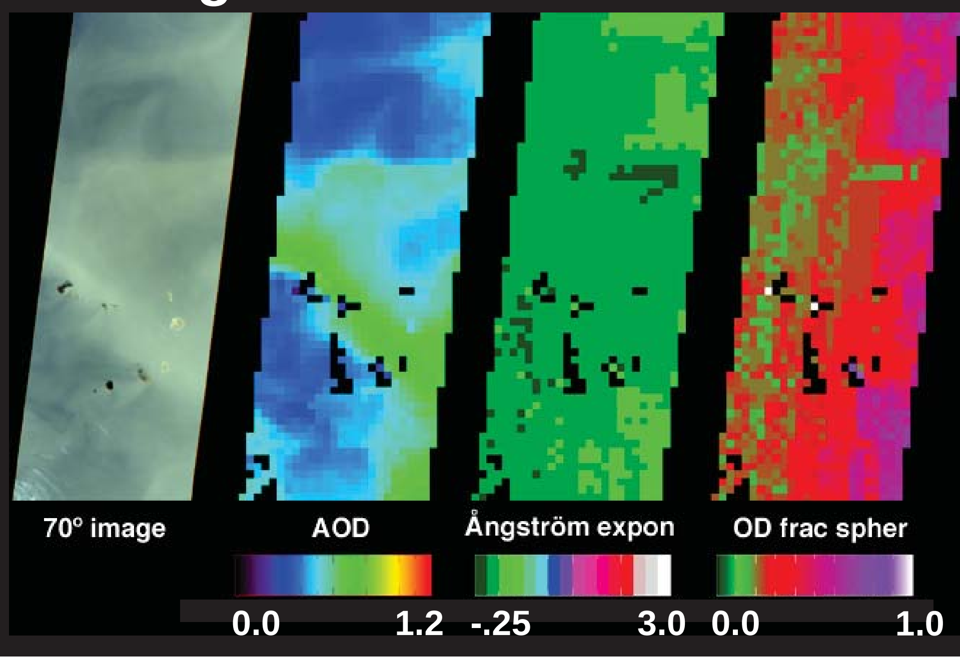
Size

Shape



Medium
Spherical
Smoke
Particles

Dust blowing off the Sahara Desert -- 6 February 2004



Large
Non-Spherical
Dust
Particles

Typical MODIS & MISR Data Volumes

Earth System Science → ~ 3 x 10^3 Tbit/day!

MODIS Level 1B2 ***radiances*** = ***~ 660 GB/day***

[~2.2 GB /granule x 20 granules/orbit x 15 orbits/day]

MISR Level 1B2 ***radiances*** = ***~ 33 GB/day***

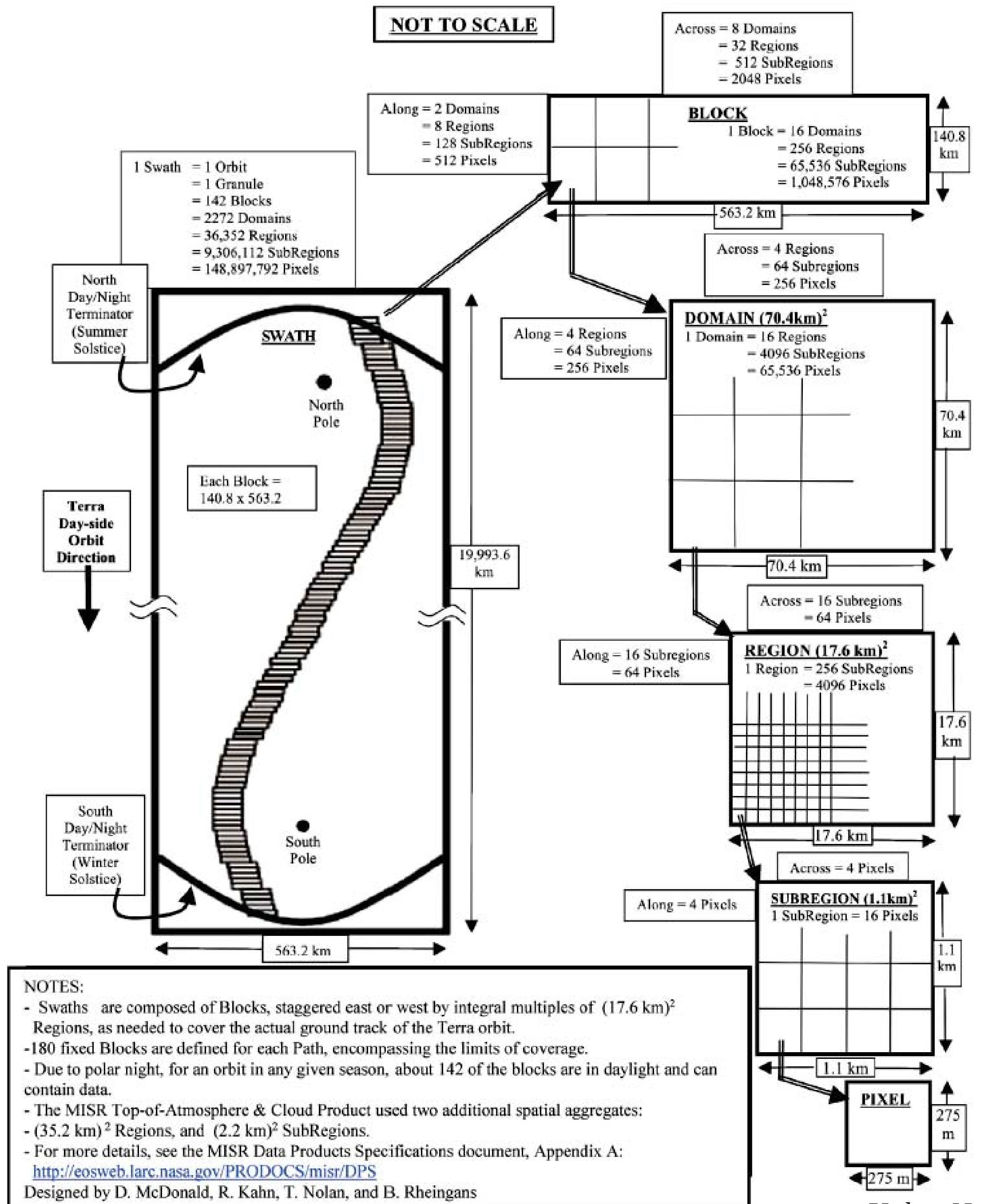
[~2.2 GB /orbit x 15 orbits/day]

MODIS Level 2 ***Aerosol*** = ~40 MB/orbit, ***~ 600 MB/day***

MISR Level 2 ***Aerosol*** = ~25 MB/orbit, ***~ 375 MB/day***

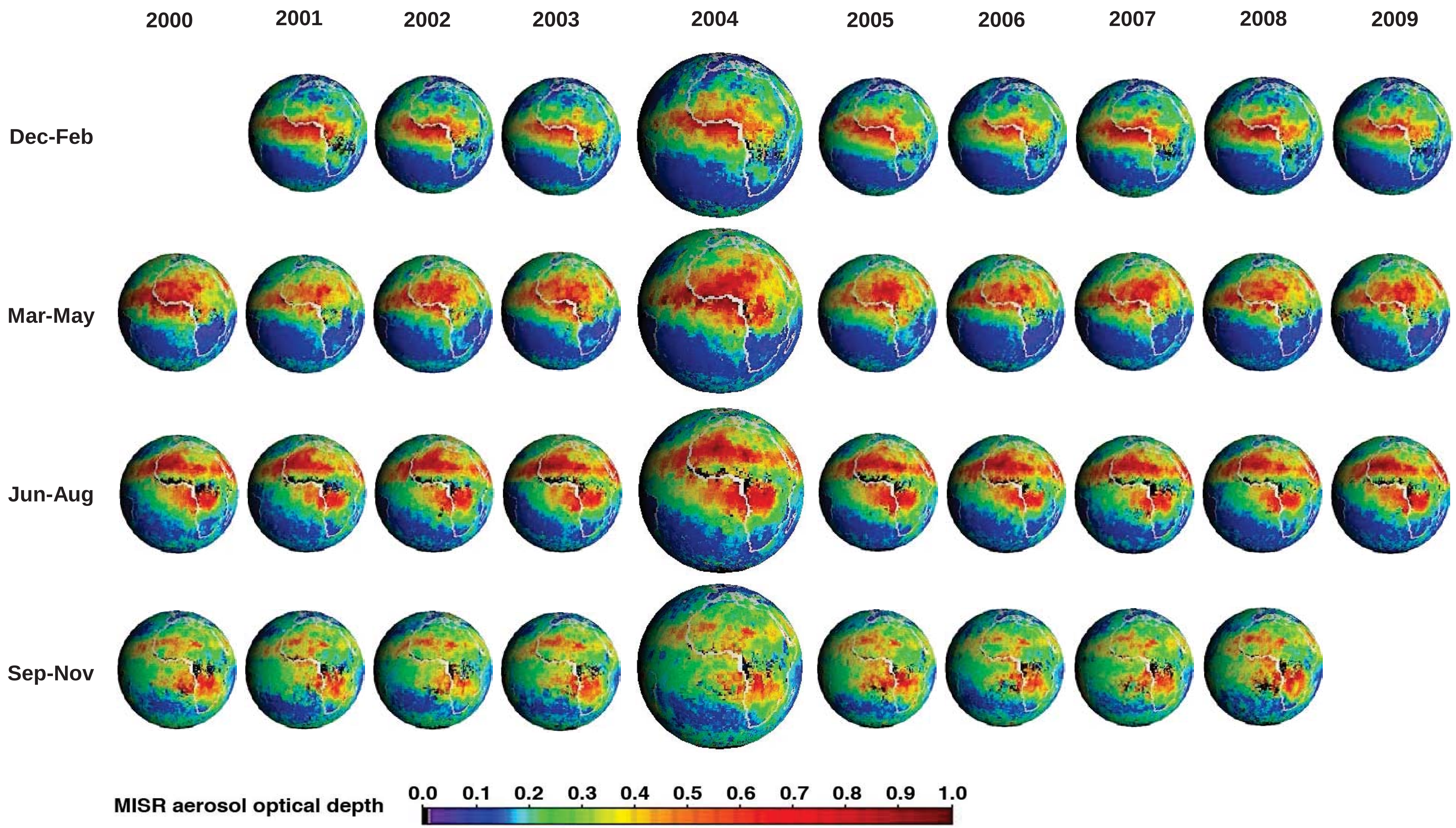
14^{+} YEARS of MISR & MODIS data

MISR Product Organization



Kahn, Nelson, Garay et al., TGARS, 2009

Ten Years of Seasonally Averaged Mid-visible Aerosol Optical Depth from **MISR**

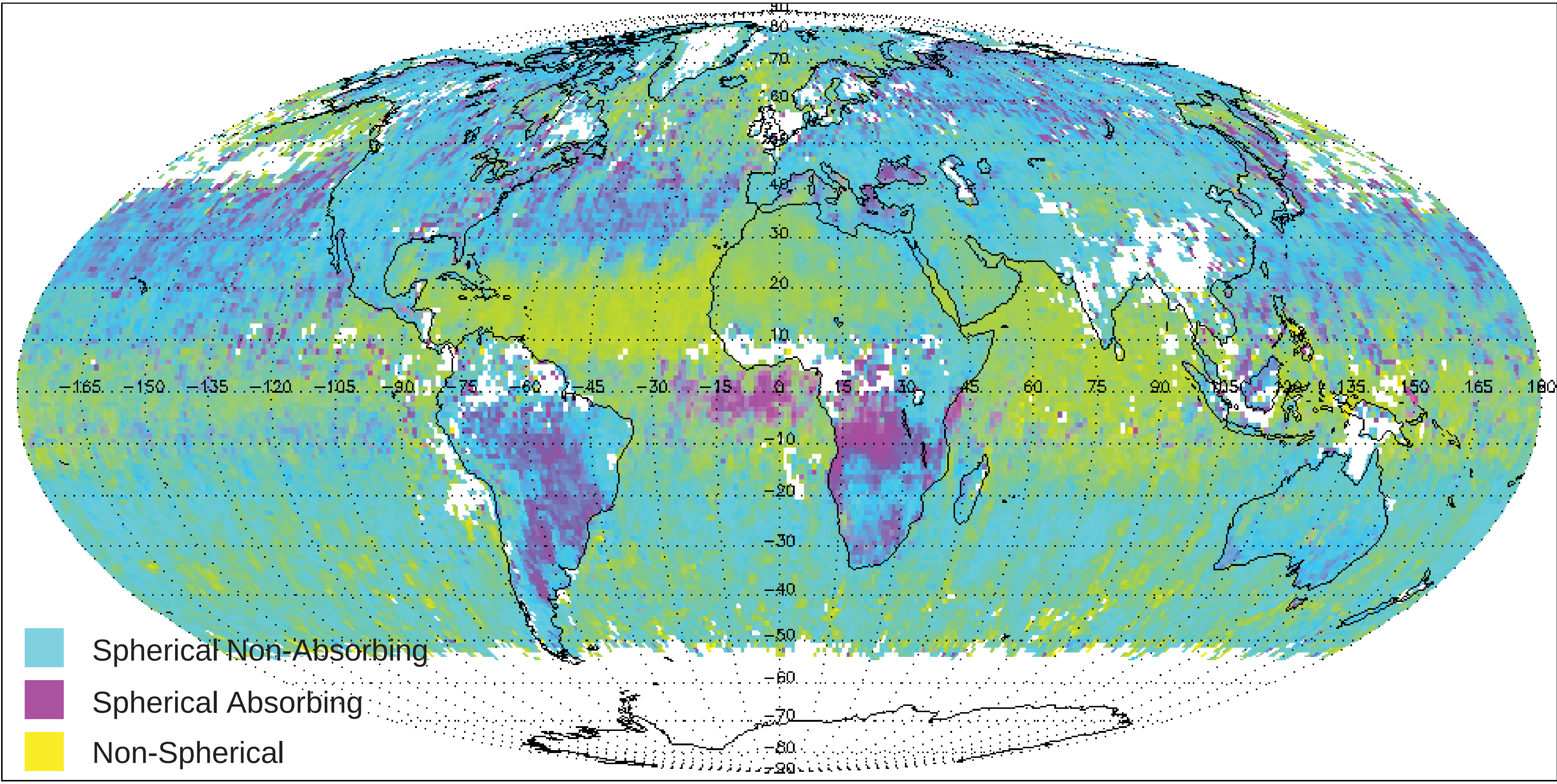


…includes bright desert dust source regions

MISR Team, JPL and GSFC

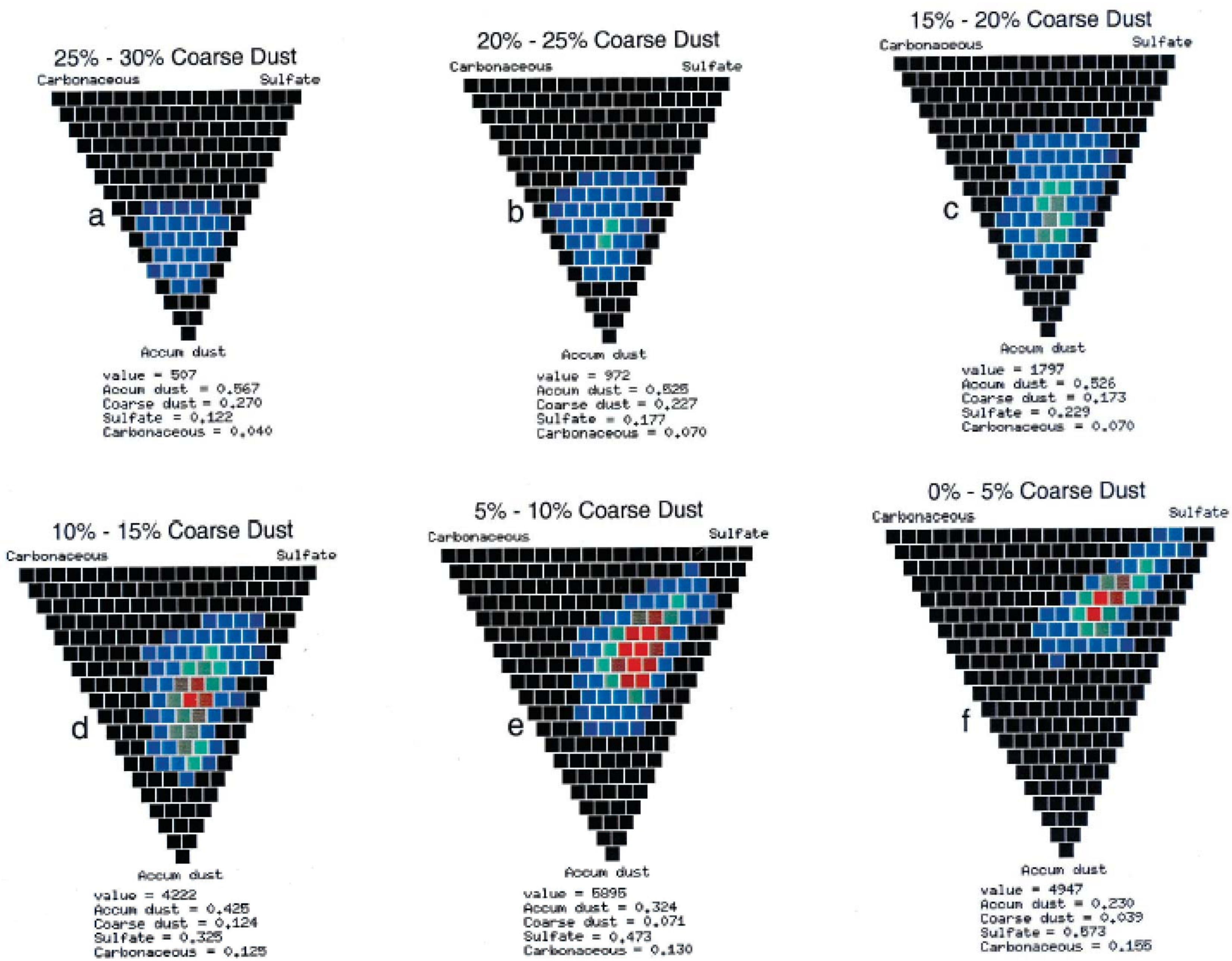
MISR *Aerosol Type* Distribution

MISR Version 22, July 2007



Kahn, Gaitley, Garay, et al., JGR 2010

Cluster Analysis: Identifying Aerosol Air Mass Types



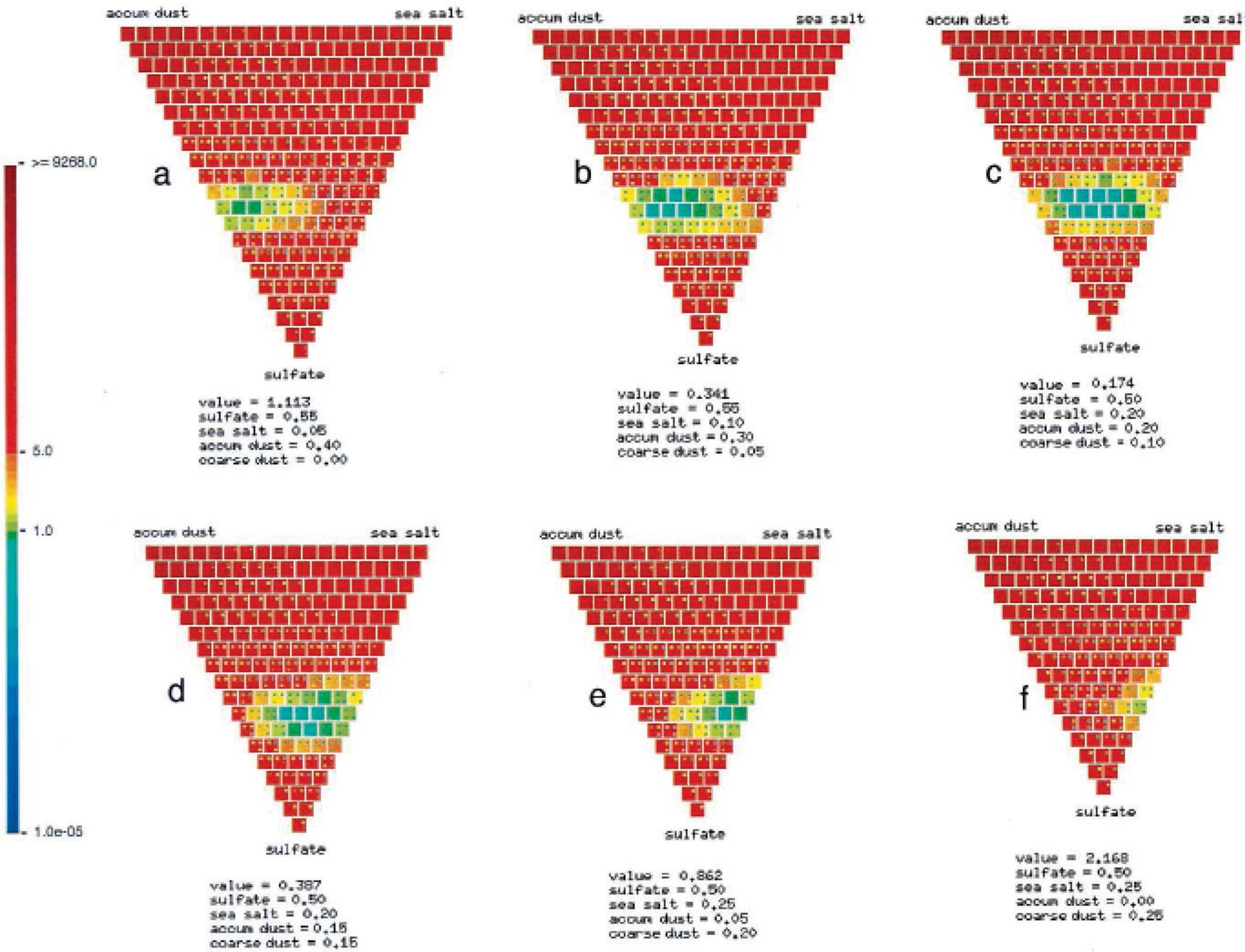
Kahn et al., JGR

Pre-Launch, *Model-Derived* Aerosol Air Mass Types

CLASSIFICATION	Component 1	Component 2	Component 3	Component 4
1. **Carbonaceous + Dusty Maritime**	Sulfate	Sea Salt	Carbonaceous	Accum. Dust
1a.	**0.67**	0.13	0.10	0.10
1b.	0.41	0.13	**0.27**	**0.19**
1c.	0.40	**0.32**	0.17	0.11
2. **Dusty Maritime + Coarse Dust**	Sulfate	Sea Salt	Accum. Dust	Coarse Dust
2a.	**0.52**	0.17	0.21	0.10
2b.	0.29	0.13	**0.39**	**0.19**
3. **Carbonaceous + Black Carbon Maritime**	Sulfate	Sea Salt	Carbonaceous	Black Carbon
3a.	**0.51**	0.18	0.26	0.05
3b.	0.35	0.10	**0.47**	**0.08**
4. **Carbonaceous + Dusty Continental**	Sulfate	Accum. Dust	Coarse Dust	Carbonaceous
4a.	**0.61**	0.21	0.05	0.10
4b.	0.40	**0.35**	0.09	**0.16**
4c.	0.22	**0.51**	**0.16**	0.11
5. **Carbonaceous + BC Continental**	Sulfate	Accum. Dust	Carbonaceous	Black Carbon
5a.	**0.59**	0.12	0.23	0.06
5b.	0.25	0.12	**0.54**	0.09
5c.	0.44	**0.23**	**0.26**	0.07

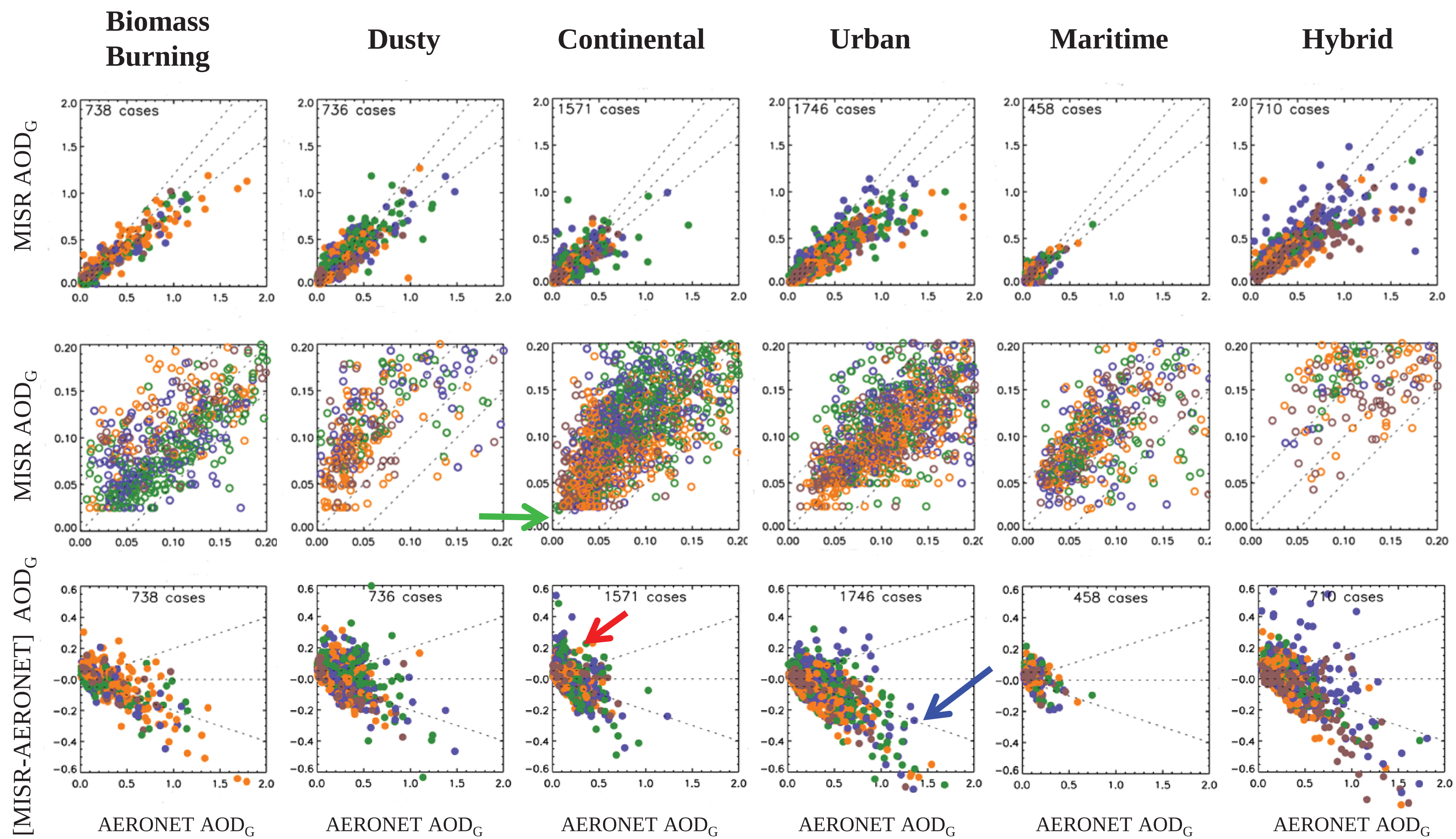
Kahn et al., JGR

4-Dimensional, 4-Parameter Sensitivity Tests



Kahn et al., JGR

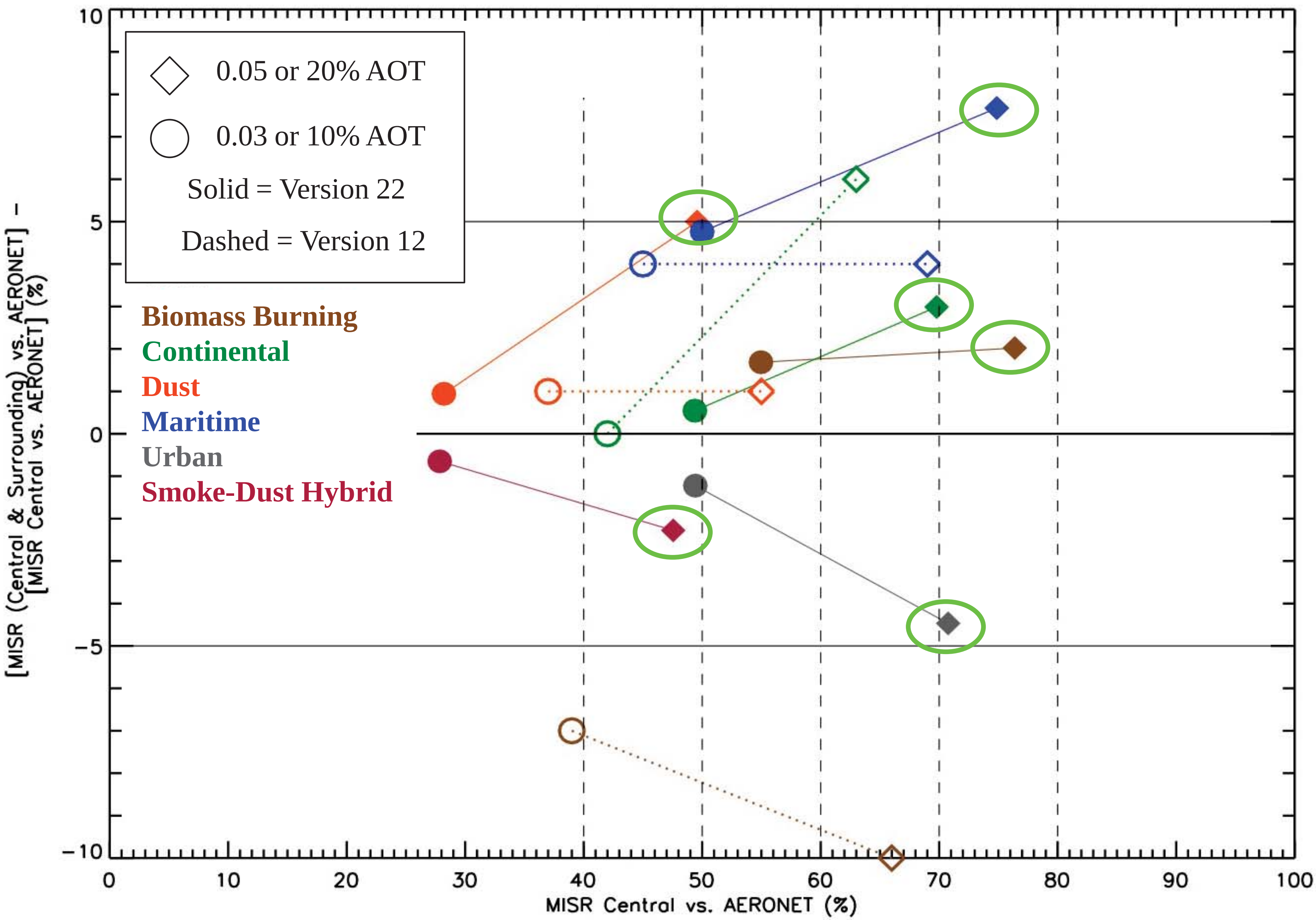
MISR V22-AERONET AOD Comparison for 5,156 Coincidences



Kahn, Gaitley et al., JGR 2010

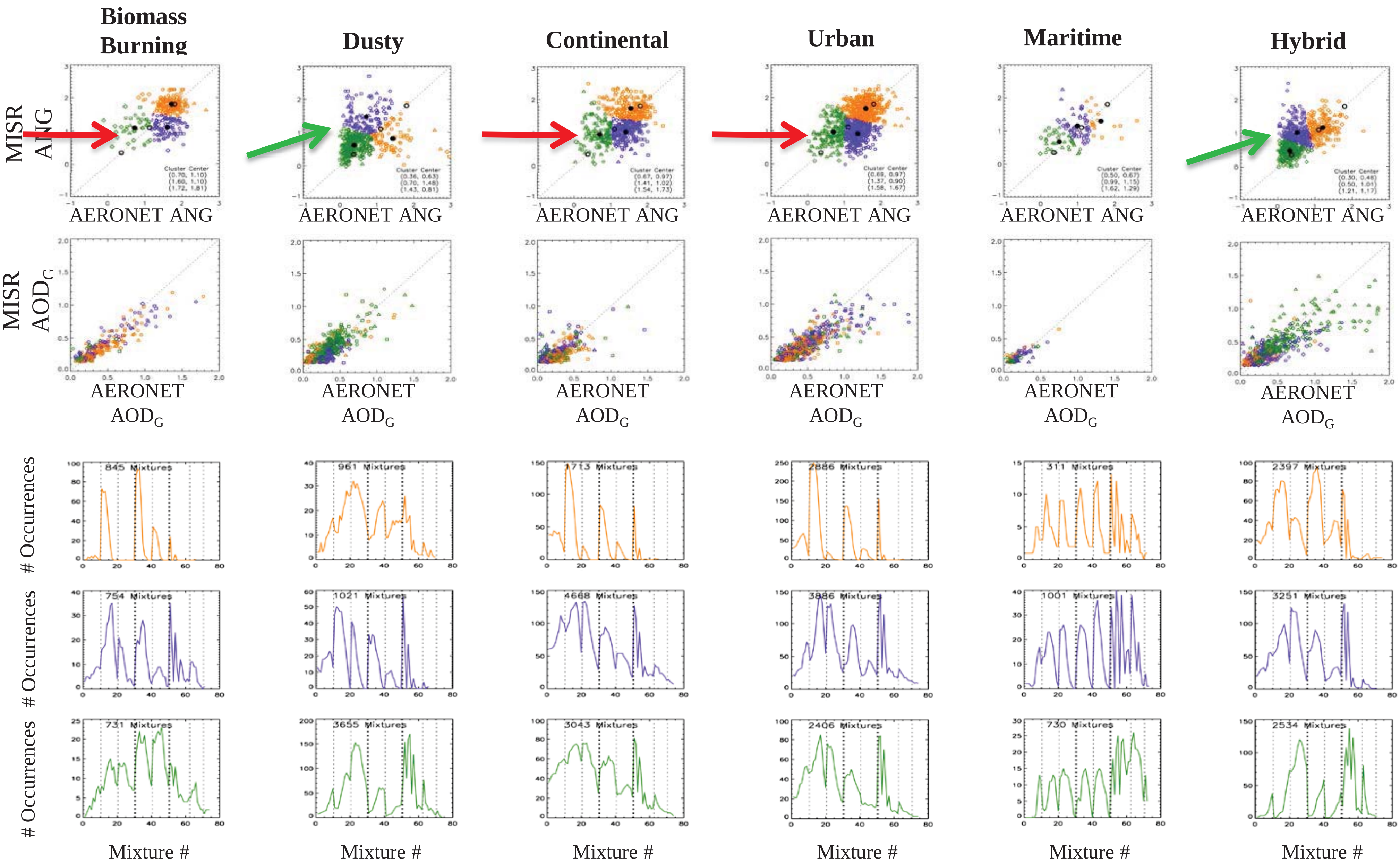
MISR-AERONET AOD Comparison for 5,156 Coincidences

MISR Version 22 – Stratified by expected aerosol air mass type

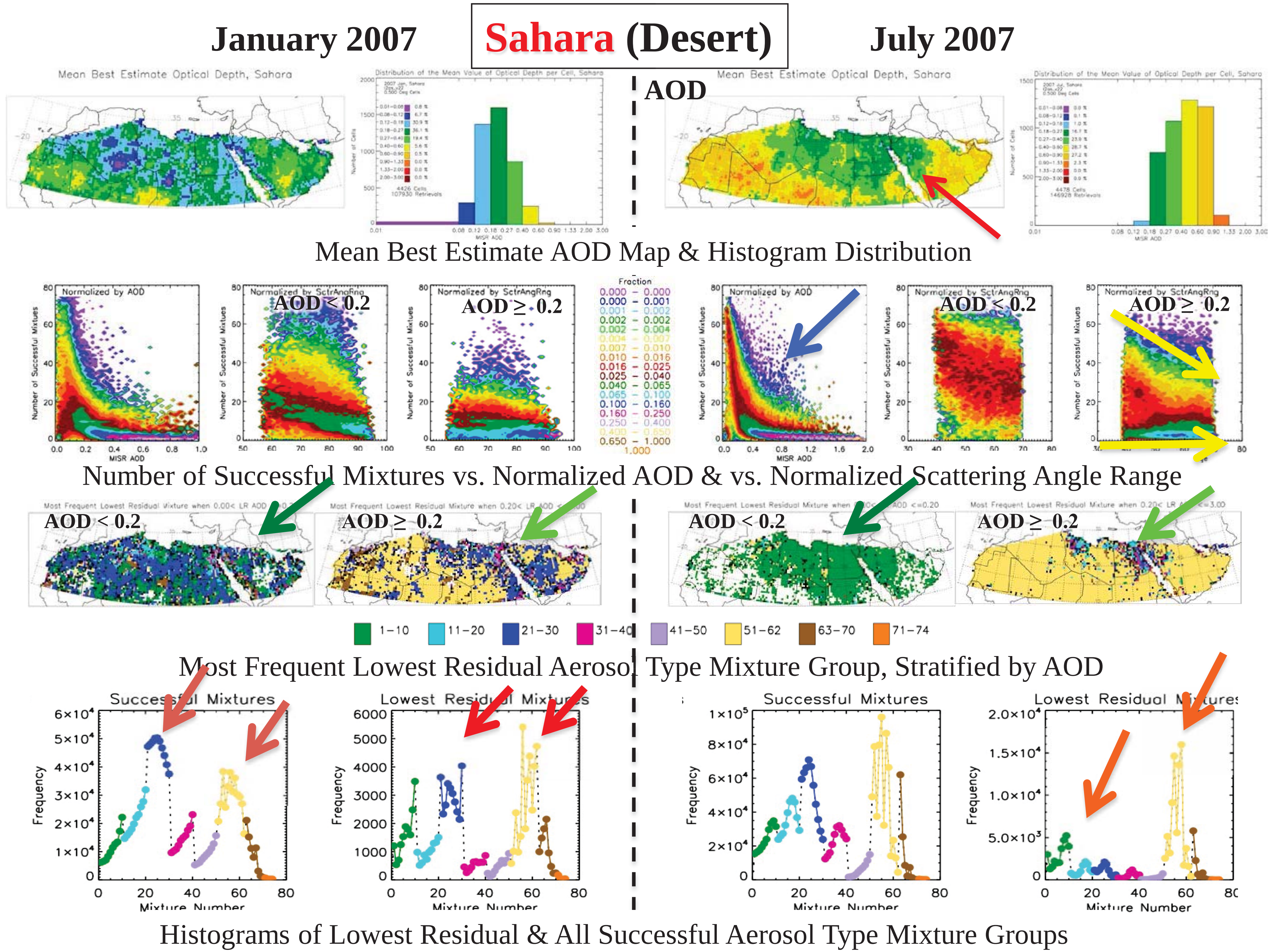


Kahn, Gaitley et al., JGR 2010

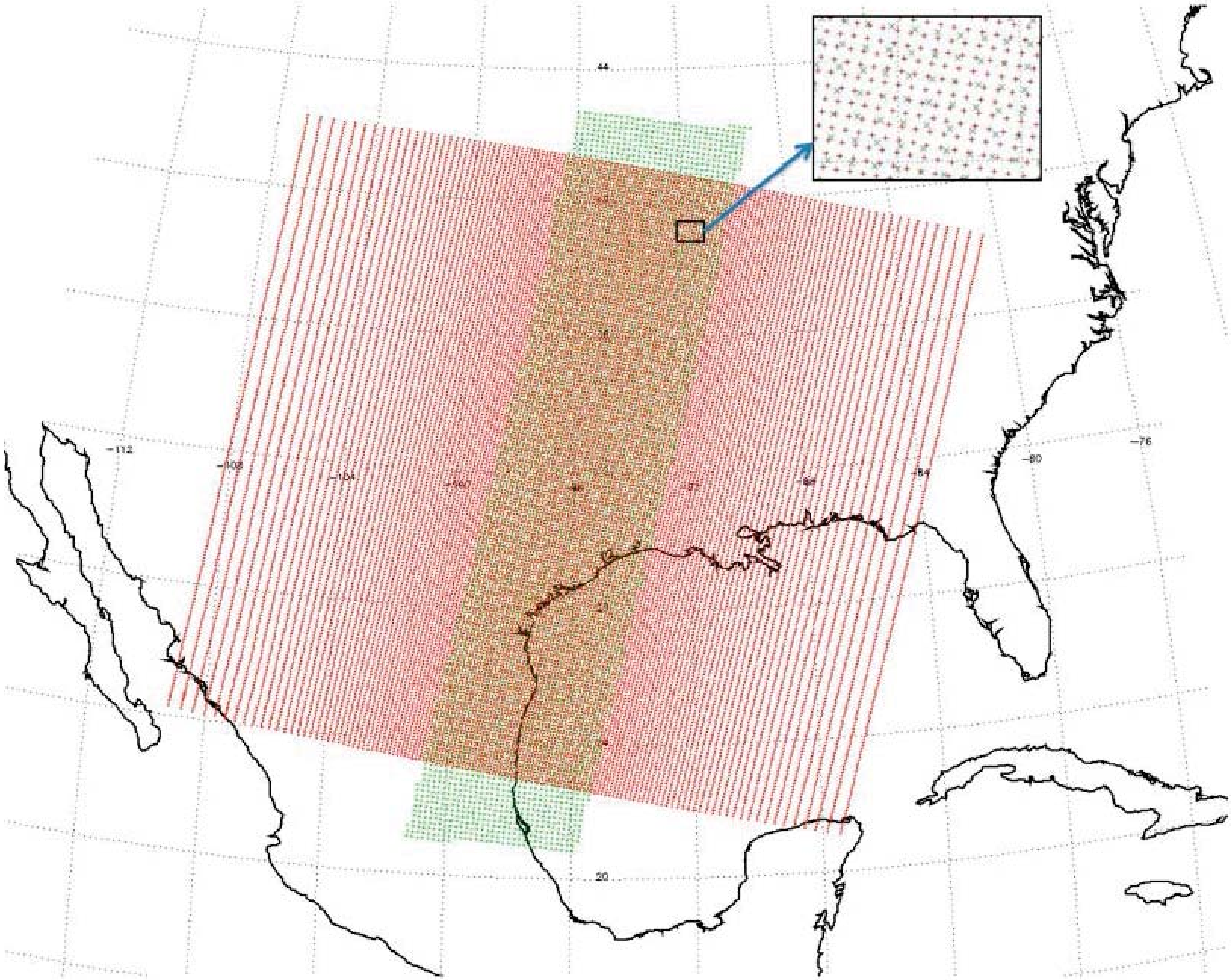
Needed Aerosol Types – ***Medium Spherical Mode***



Kahn, Gaitley, Garay, et al., JGR 2010


January 2007
Sahara (Desert)
July 2007
AOD
Mean Best Estimate Optical Depth, Sahara
Distribution of the Mean Value of Optical Depth per Cell, Sahara
Number of Cells
MISR AOD
4426 Cells
107930 Retrievals
4478 Cells
146928 Retrievals
Mean Best Estimate AOD Map & Histogram Distribution
Normalized by AOD
Normalized by SctrAngRng
AOD < 0.2
AOD ≥ 0.2
Number of Successful Mixtures
MISR AOD
Fraction
0.000 – 0.000
0.000 – 0.001
0.001 – 0.002
0.002 – 0.002
0.002 – 0.004
0.004 – 0.007
0.007 – 0.010
0.010 – 0.016
0.016 – 0.025
0.025 – 0.040
0.040 – 0.065
0.065 – 0.100
0.100 – 0.160
0.160 – 0.250
0.250 – 0.400
0.400 – 0.650
0.650 – 1.000
1.000
Number of Successful Mixtures vs. Normalized AOD & vs. Normalized Scattering Angle Range
AOD < 0.2
AOD ≥ 0.2
1–10
11–20
21–30
31–40
41–50
51–62
63–70
71–74
Most Frequent Lowest Residual Aerosol Type Mixture Group, Stratified by AOD
Successful Mixtures
Lowest Residual Mixtures
Frequency
Mixture Number
Histograms of Lowest Residual & All Successful Aerosol Type Mixture Groups

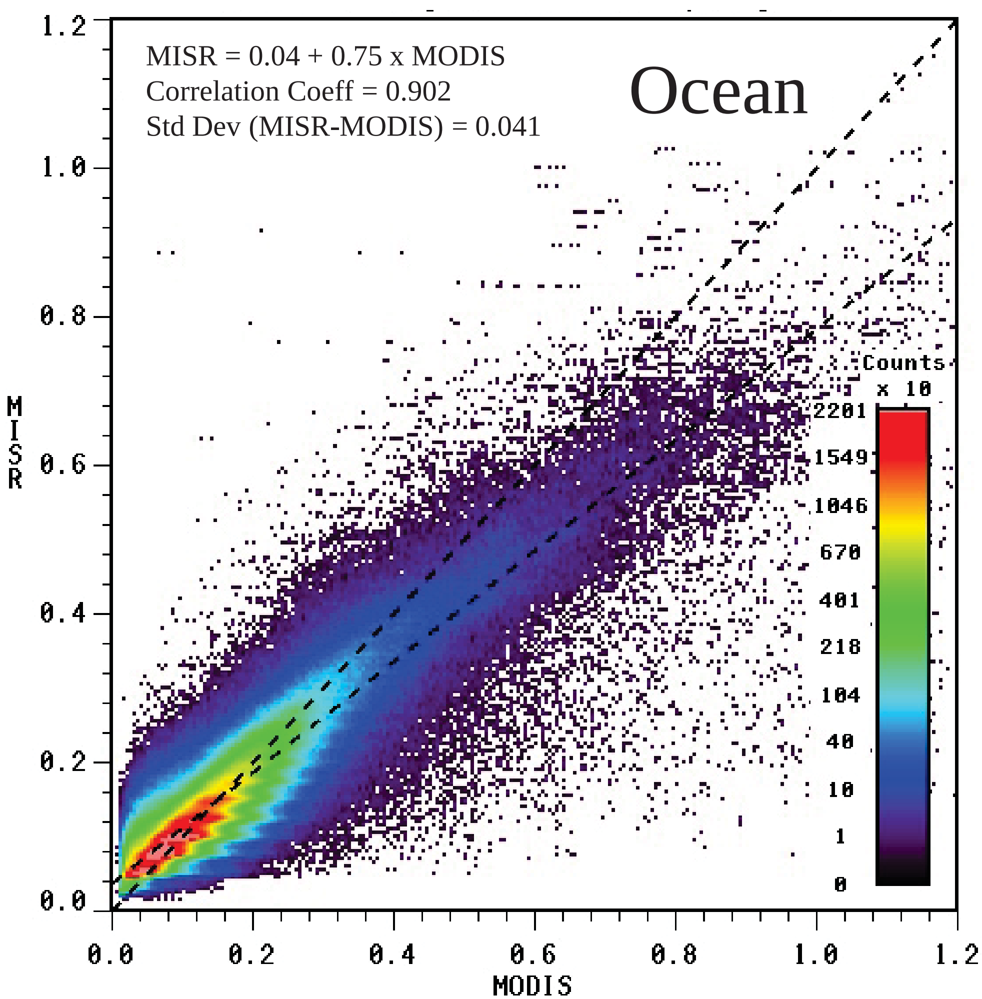
MISR and MODIS Footprints – ***Not Exactly Co-located***

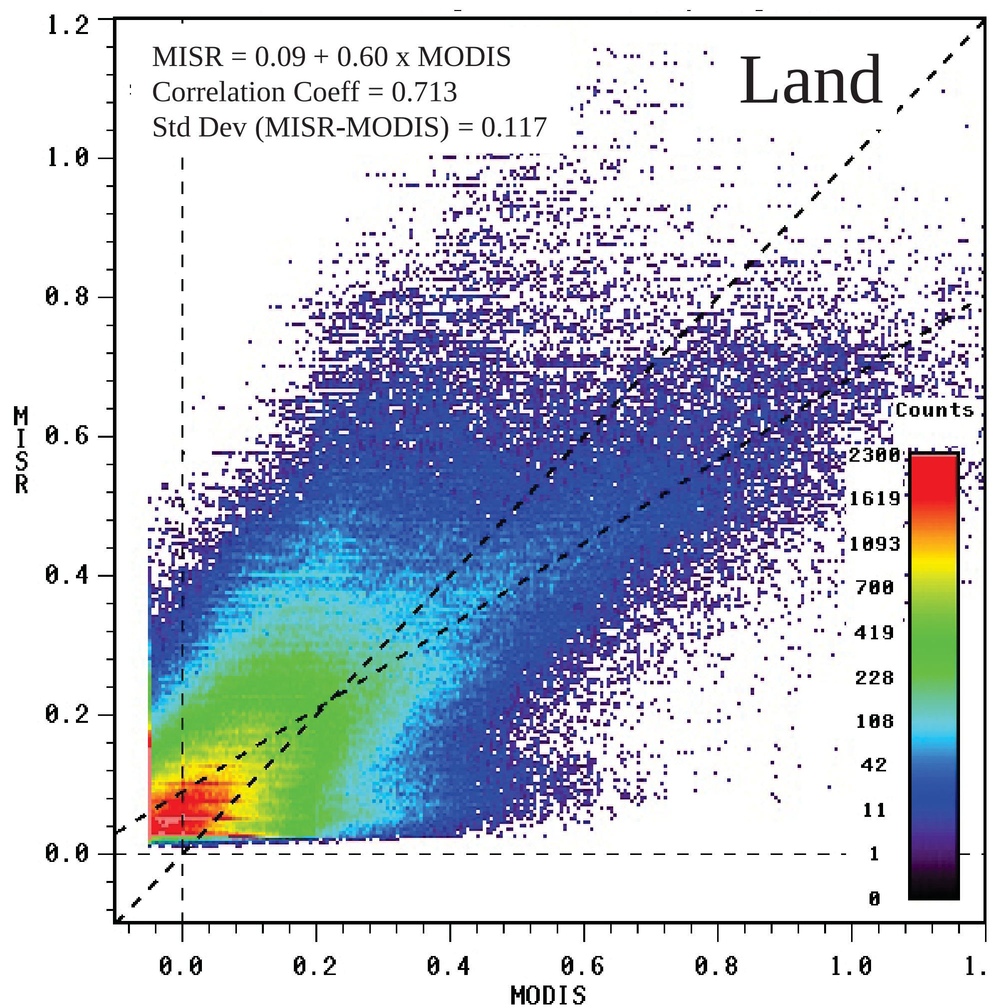


Kahn, Nelson, Garay et al., TGARS, 2009

MISR-MODIS *Aerosol Optical Depth* Comparison

[MISR V22 vs. MODIS/Terra Collection 5; January 2006 Coincident Data]



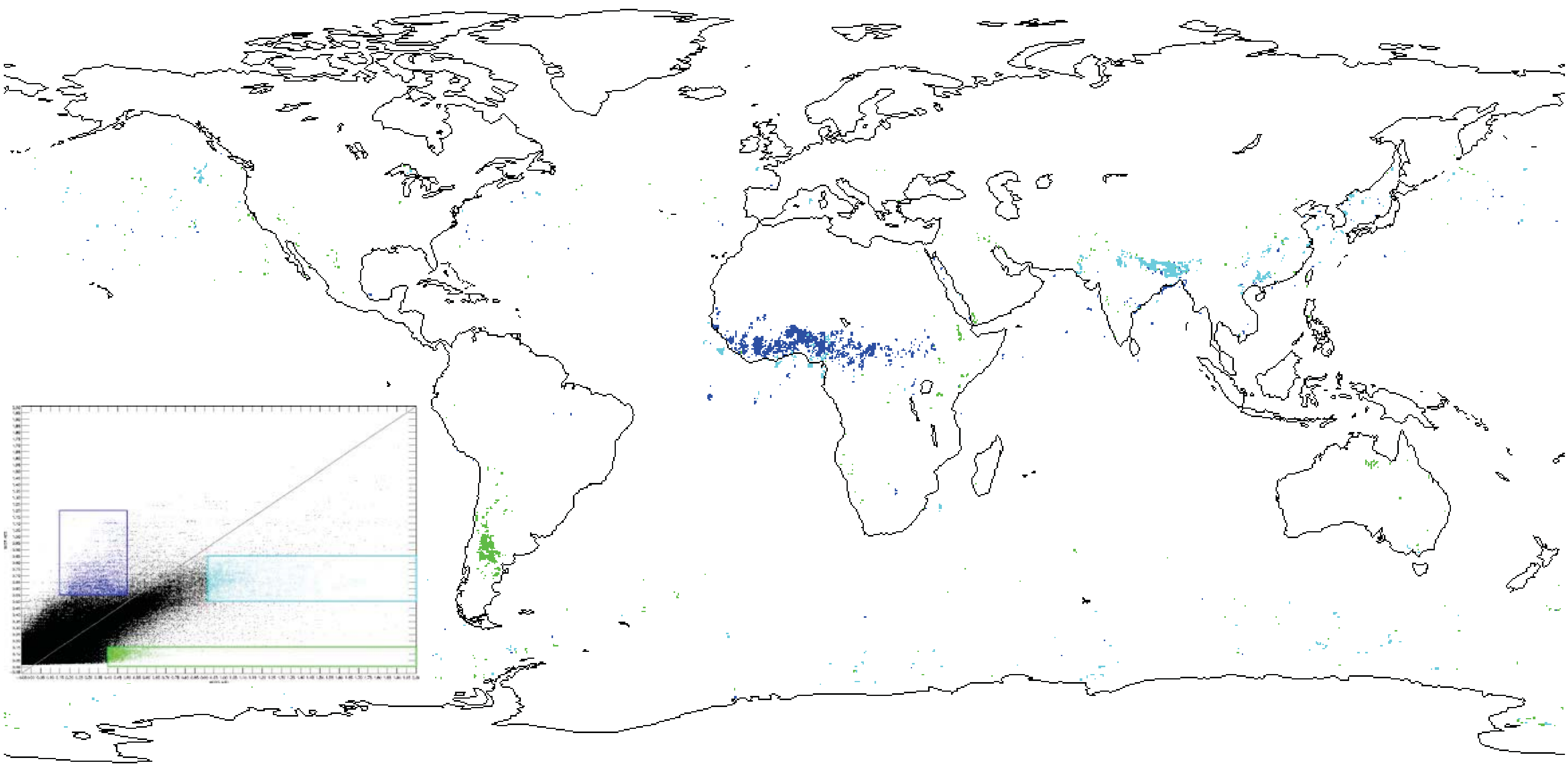


Over-ocean regression coefficient **0.90**
Regression line slope 0.75
MODIS QC ≥ 1

Over-land regression coefficient **0.71**
Regression line slope 0.60
MODIS QC = 3

Kahn, Nelson, Garay et al., TGARS 2009

MISR-MODIS Coincident AOT ***Outlier Clusters***



Dark Blue [MISR > MODIS] – N. Africa ***Mixed Dust & Smoke***

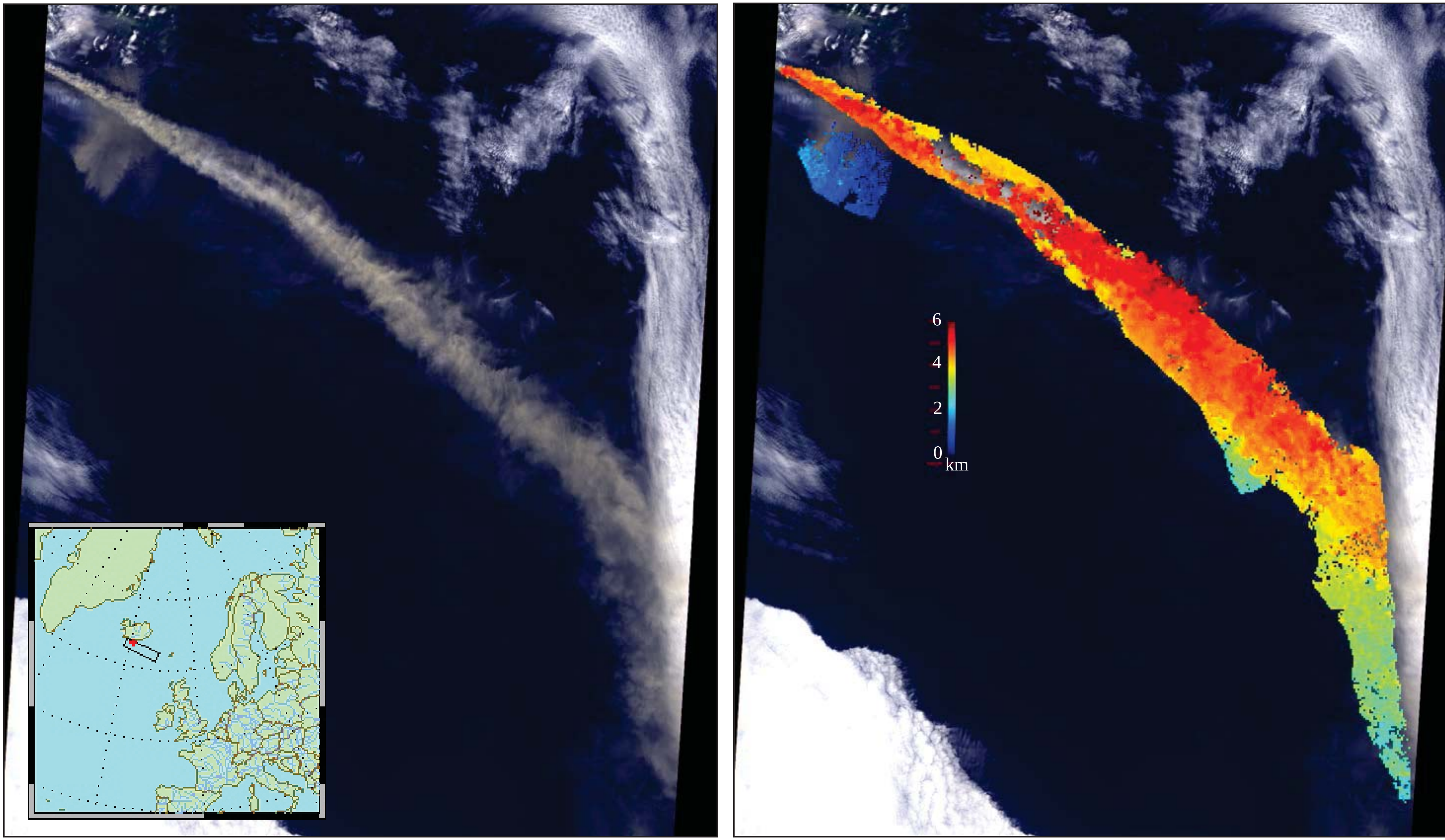
Cyan [MODIS > MISR, AOD large] – Indo-Gangetic Plain ***Dark Pollution Aerosol***

Green [MODIS >> MISR] – Patagonia and N. Australia ***MODIS Unscreened Bright Surface***

Kahn et al., TGARS 2009

MISR Stereo-Derived Plume Heights

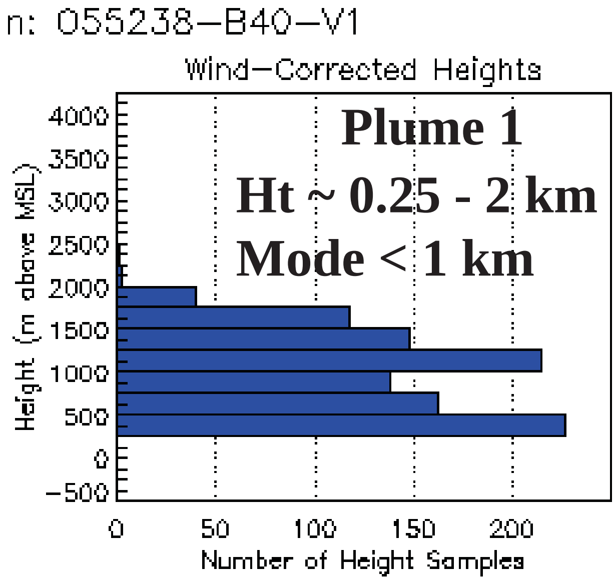
07 May 2010 Orbit 55238 Path 216 Blk 40 UT 12:39



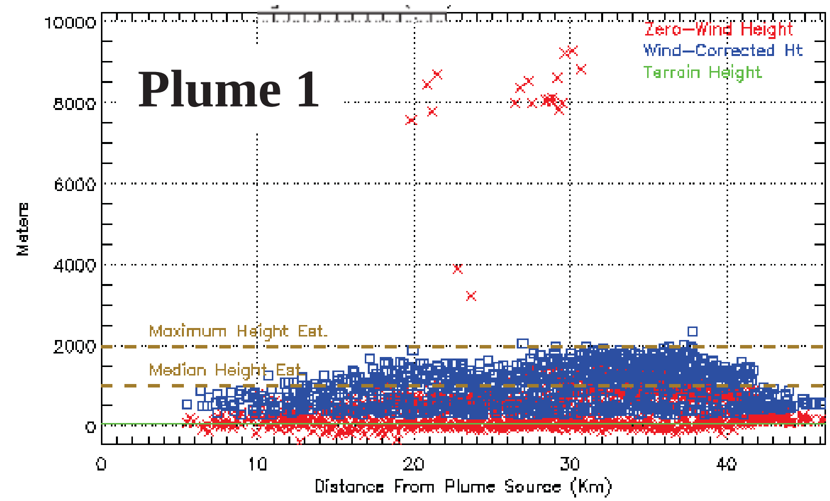
D. Nelson and the MISR Team, JPL and GSFC

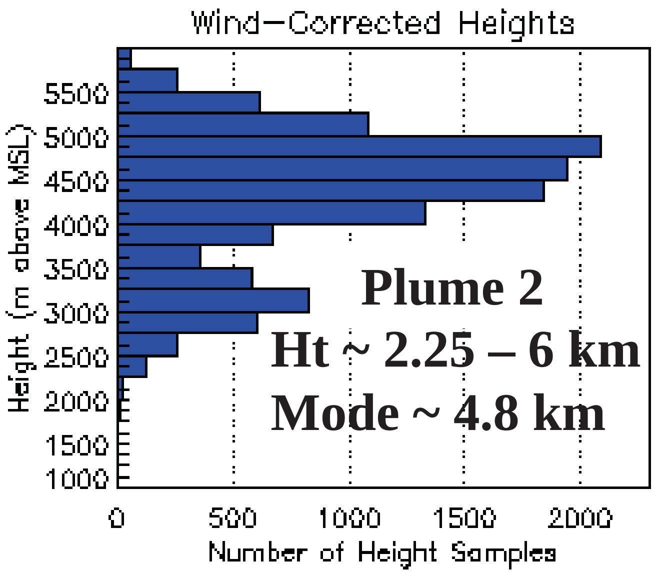
MISR Stereo-Derived Plume Heights

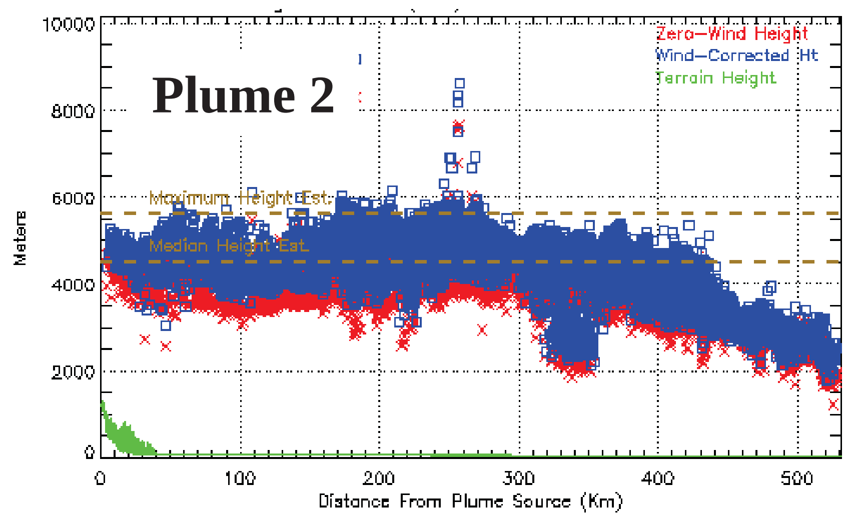
07 May 2010 Orbit 55238 Path 216 Blk 40 UT 12:39



Height: Blue = Wind-corrected



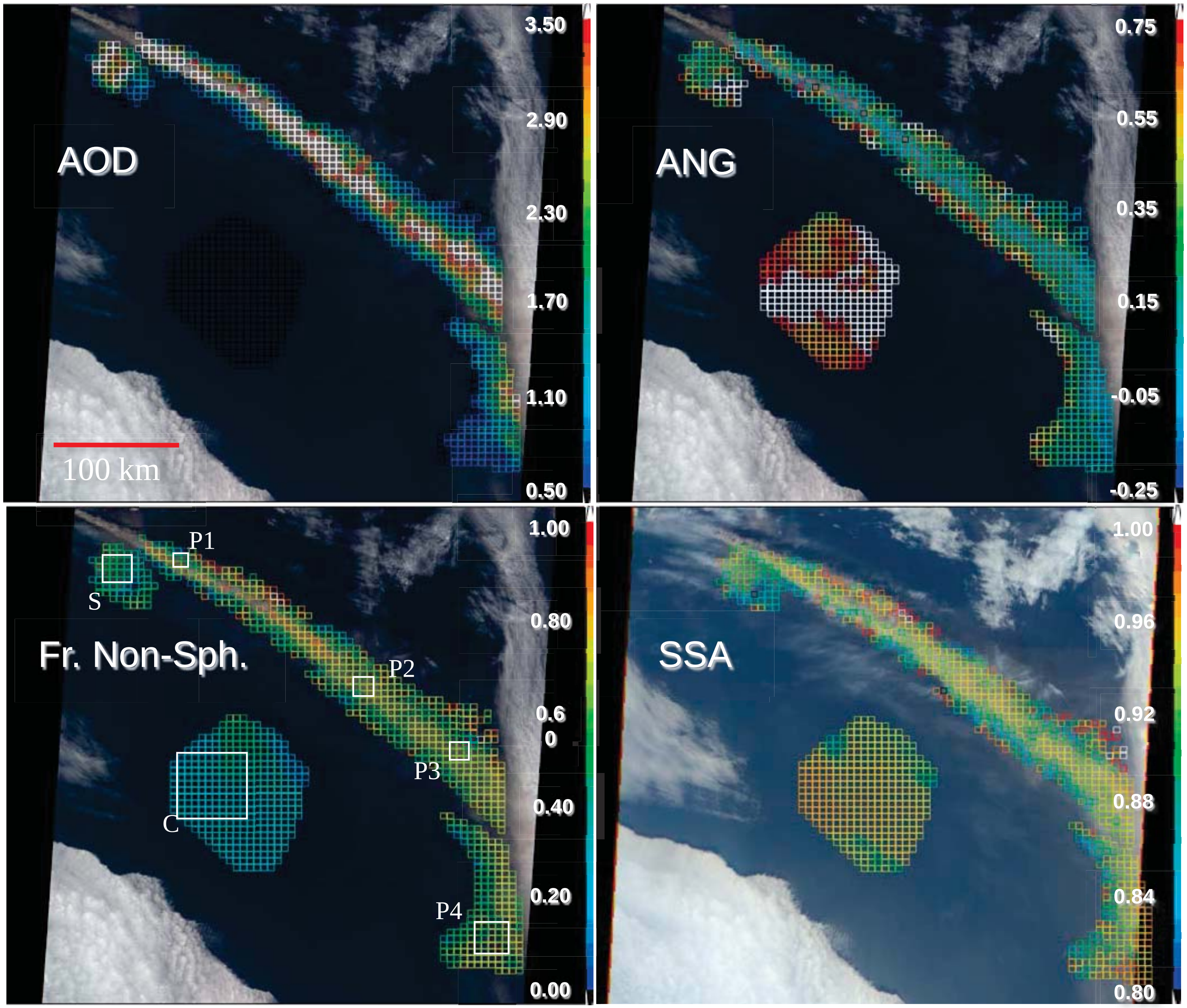




D. Nelson and the MISR Team

MISR Research Aerosol Retrievals

07 May 2010 Orbit 55238 Path 216 Blk 40 UT 12:39



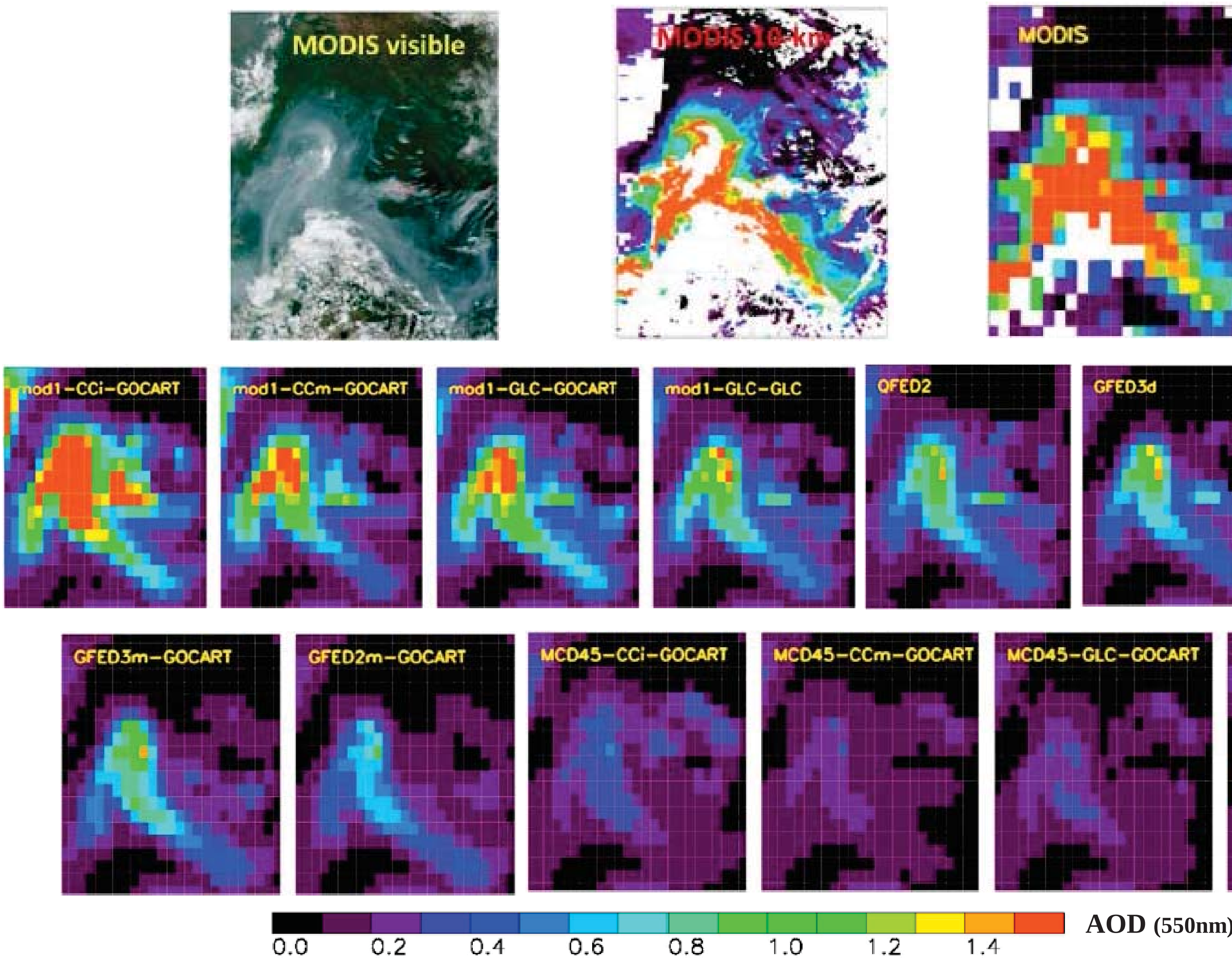
Plume Particles

- Distinct from background
  - -- ***larger***, ***darker***
  - -- ***much higher AOD***
- ***Non-spherical*** dominated
- Brighten downwind
- Tend to decrease in size downwind

Kahn & Limbacher, ACP 2012

MODIS-GoCART Total Column AOD Comparisons

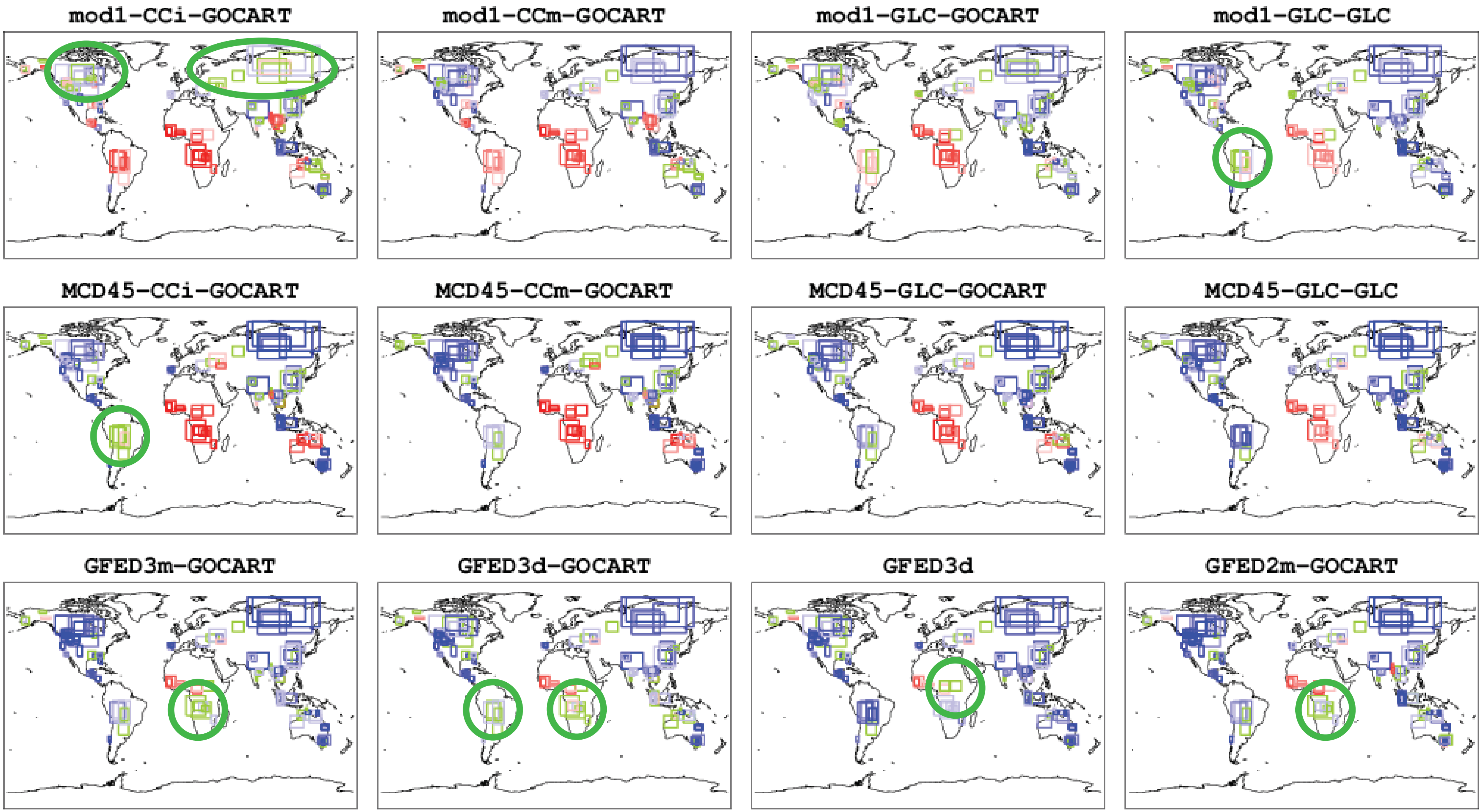
Sample Case: Siberia July 20 2006



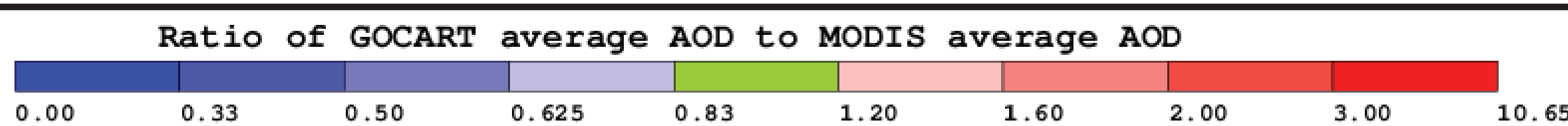
Petrenko et al., JGR, 2012

Ratio of GOCART to MODIS average AOD

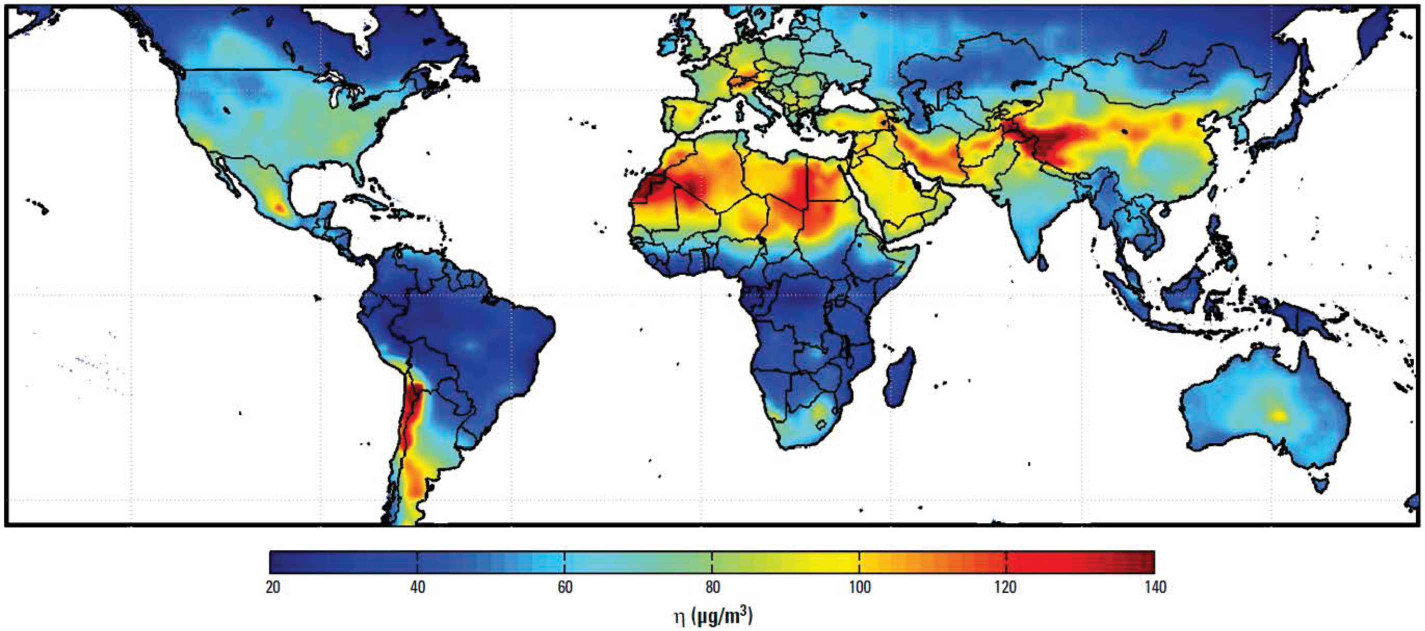
For each case, for 12 emission estimates



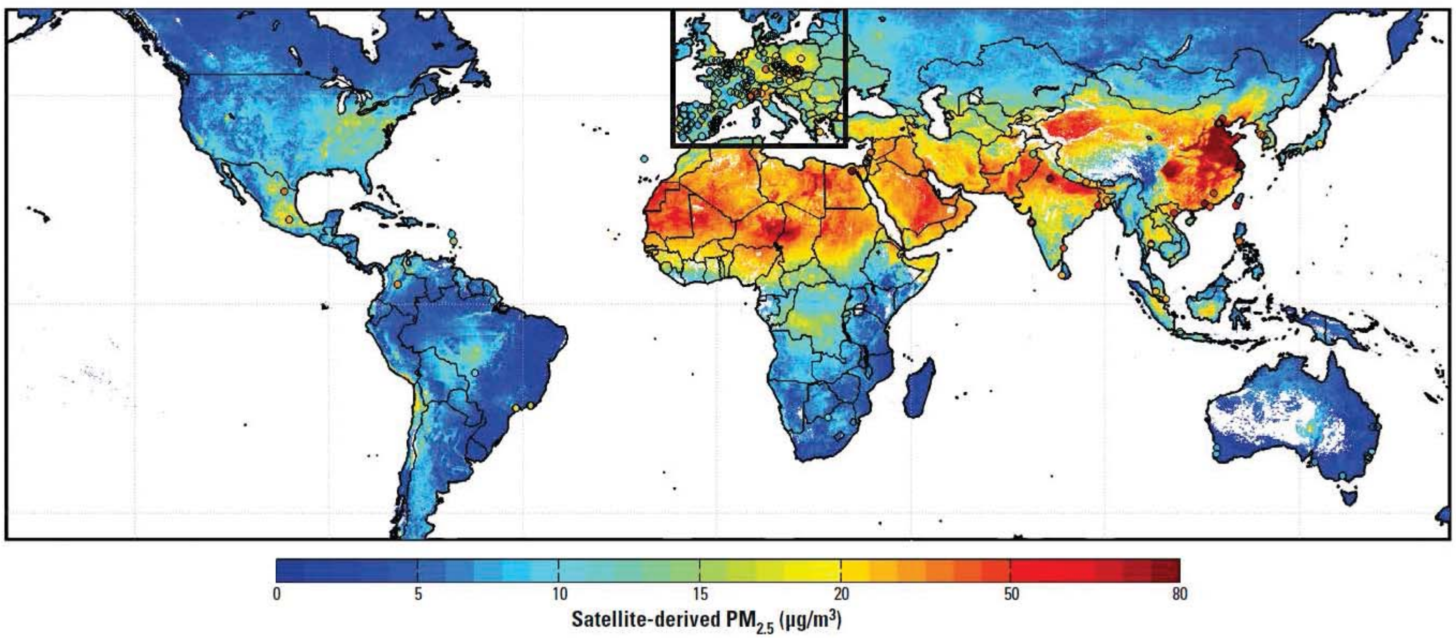
Systematic regional patterns; some parameterizations work better in certain regions



Air Quality: BL Aerosol Concentration
[MISR + MODIS] AOD & GEOS-Chem Vertical Distribution

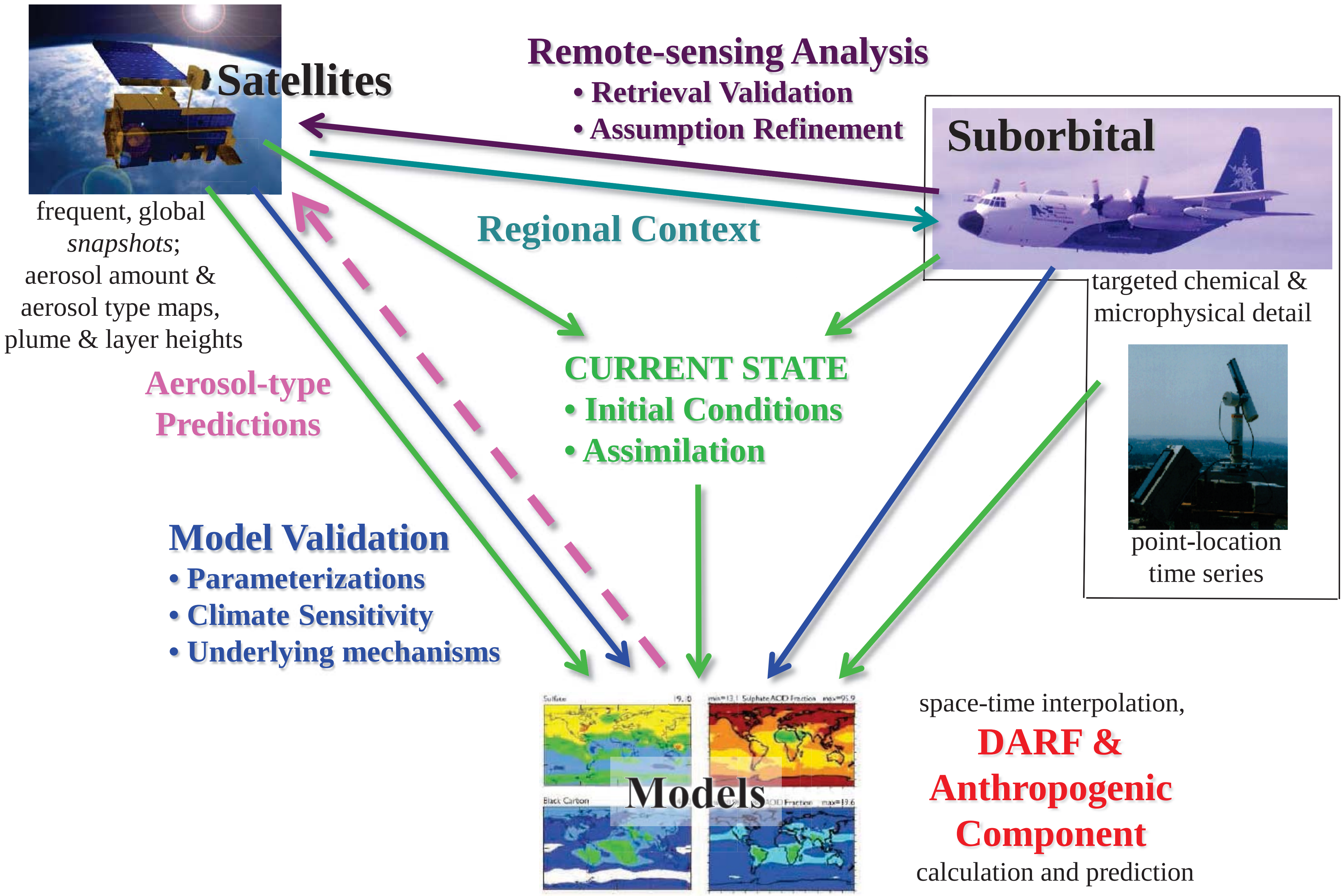


[BL $PM_{2.5}$] / [Total-col. AOD]
2001- 2006



Derived $PM_{2.5}$

Van Donkelaar et al., Environ. Health Prespect. 2010



Kahn, Survy. Geophys. 2012

However, the ***Biggest*** Issue We Face Is:

People ***Over-Interpreting the Data***

<u>And</u>:

The Easier It is to make "pretty plots,"
The more this tends to happen…

Thoughts??